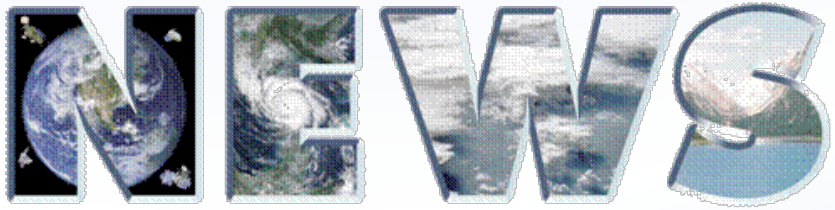
August 2010 January 2011 Highlights

NASA ENERGY AND WATER CYCLE STUDY



NEWS Challenge:

Document and enable improved, observationally-based, predictions of water and energy cycle consequences of Earth system variability and change.

Program Manager: J. Entin (NASA-HQ)
Project Scientist: P. Houser (GMU)
Sr. Project Scientist: R. Schiffer (UMBC/GEST)
Focus Area Liaison: D. Belvedere (UMBC/GEST)

NEWS Working Group Co-Chairs:
Drought & Flood Extremes: X. Dong & Y. Deng
Evaporation & Latent Heating: J. Famiglietti & C.A. Clayson
Energy & Water Cycle Climatology: M. Rodell & T. L'Ecuyer
Modeling & Water Cycle Prediction: M. Bosilovich & Y. Hu

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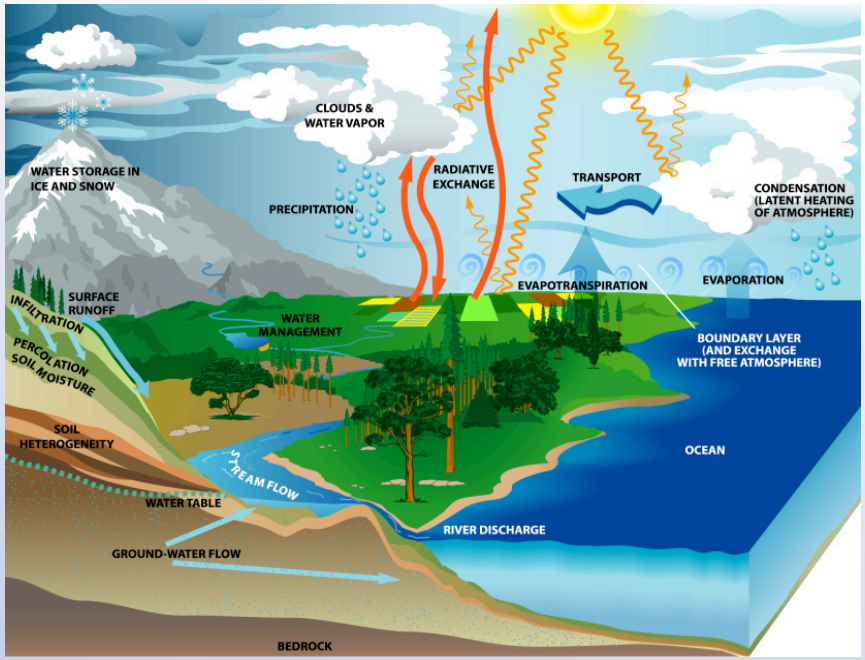
The Water and Energy Cycle

Is the water cycle accelerating?



Why NEWS?

Need the collective of NASA & community information and expertise to ask (and define) the larger questions

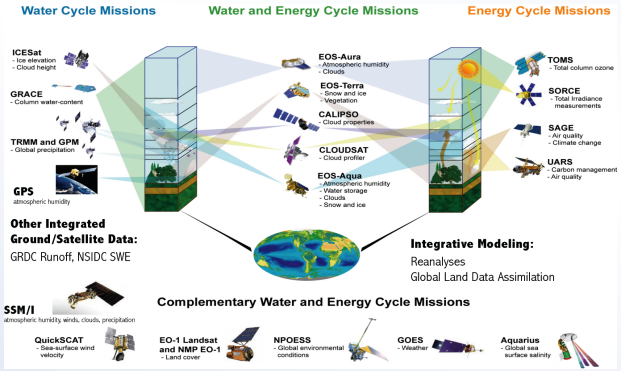
(aka) Need the whole to be more than the sum of the parts

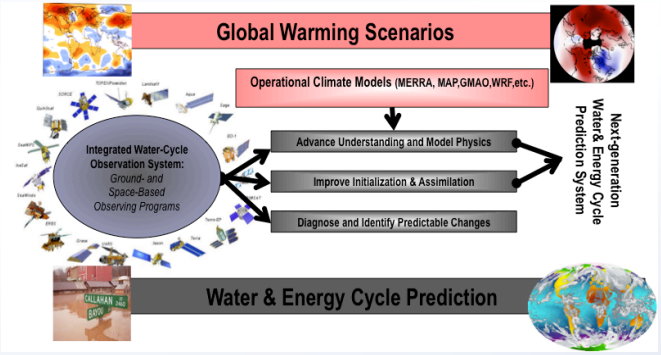
Why study the water & Energy cycle?

1. *Water exists in all three phases in the climate system and the phase transitions are a significant factor in the regulation of the global and regional energy balances*
2. *Water vapor in the atmosphere is the principal greenhouse gas and clouds at various levels and composition in the atmosphere represent both positive and negative feedback in climate system response*
3. *Water is the ultimate solvent and global biogeochemical and element cycles are mediated by the dynamics of the water cycle*
4. *Water is the element of the Earth system that most directly impacts and constraint human society and its well-being.*

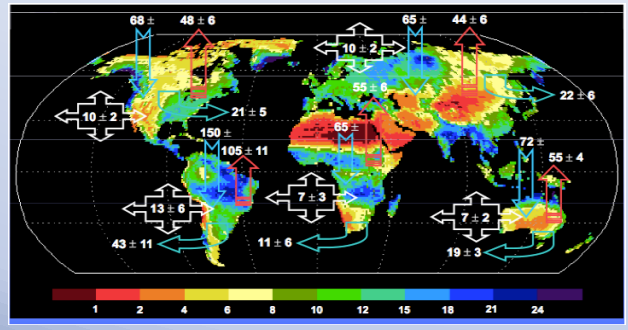
To Make Decisive Advances in Water and Energy Cycle Prediction, We Must:

•Develop a discipline of prediction and verification through the integration of water and energy cycle observations and models.

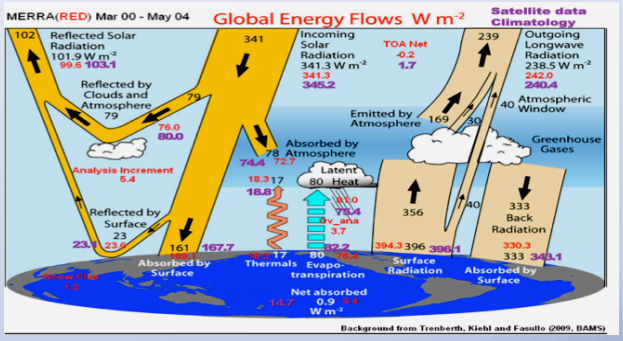




•Develop climate quality, globally complete observations of the key water- and energy-cycle rates and storages (e.g. assess and fill gaps).



•Provide an accurate accounting of the key reservoirs and fluxes associated with the global water and energy cycle, including their spatial and temporal variability.



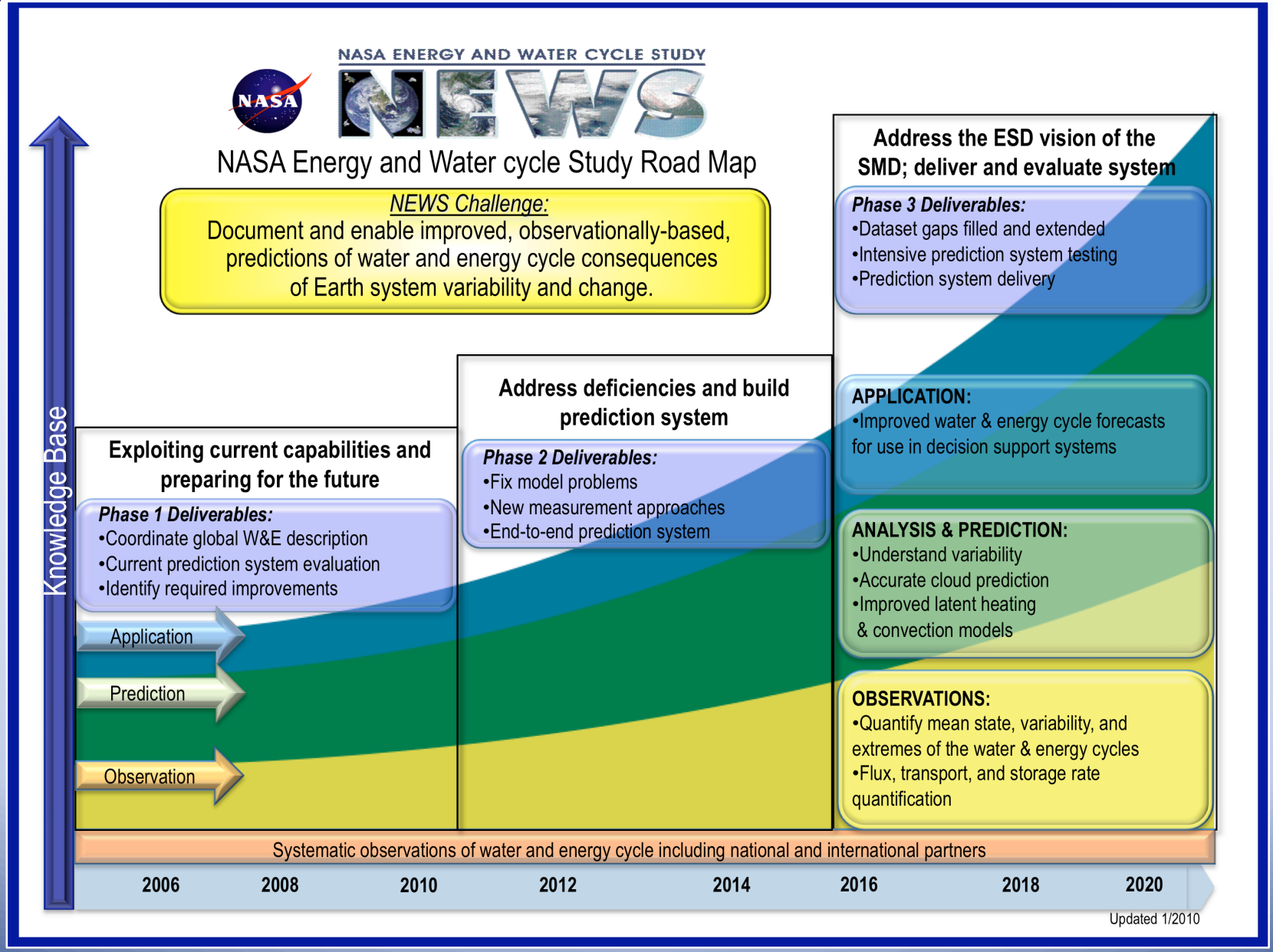
NEWS is also envisioned to make critical linkages (integration) between NASA research programs and satellite missions, other agencies, and international efforts (not just integrate amongst its members)

NEWS Components

- Focus on energy and water processes and dynamics in the climate system.
- The NEWS challenge is a global scale objective
- Integrate energy and water cycle system components (observations and predictions)
- NEWS elements: **Observation, Understanding, Models, Prediction and Consequences**
- Make **decisive progress** toward NEWS challenge
- NASA administers the energy and water cycle focus area as an **end-to-end program**
- NEWS is **an experiment** in the power of coordination, integration and teamwork

NEWS Objectives:

- Develop and deploy experimental **E&WC global observing system**
- **Document the global E&WC** by obtaining complete observational record of all associated relevant geophysical properties
- Build **fully interactive global climate model** that encompasses process-level E&WC forcings and feedbacks – ***Climate models that can predict weather-scale extremes***
- Create global surface and atmosphere **data assimilation system for E&WC variables**
- **Assess variability of the global E&WC** on time scales ranging from seasonal to decadal, and space scales ranging from regional to continental to global
- Support the **application of climate prediction capabilities** for estimating the impact of climate variability and change on water resources


NASA ENERGY AND WATER CYCLE STUDY
NEWS
NASA Energy and Water cycle Study Road Map
NEWS Challenge:
Document and enable improved, observationally-based, predictions of water and energy cycle consequences of Earth system variability and change.
Knowledge Base
Exploiting current capabilities and preparing for the future
Phase 1 Deliverables:
•Coordinate global W&E description
•Current prediction system evaluation
•Identify required improvements
Address deficiencies and build prediction system
Phase 2 Deliverables:
•Fix model problems
•New measurement approaches
•End-to-end prediction system
Address the ESD vision of the SMD; deliver and evaluate system
Phase 3 Deliverables:
•Dataset gaps filled and extended
•Intensive prediction system testing
•Prediction system delivery
APPLICATION:
•Improved water & energy cycle forecasts for use in decision support systems
ANALYSIS & PREDICTION:
•Understand variability
•Accurate cloud prediction
•Improved latent heating & convection models
OBSERVATIONS:
•Quantify mean state, variability, and extremes of the water & energy cycles
•Flux, transport, and storage rate quantification
Application
Prediction
Observation
Systematic observations of water and energy cycle including national and international partners
2006
2008
2010
2012
2014
2016
2018
2020
Updated 1/2010

Global Temperature, Water Vapor and Precipitation Variations and Trends

Adler and Gu (U. of Maryland), Huffman (GSFC/SSAI)

How global temperature changes are related to water vapor and precipitation changes on both inter-annual and inter-decadal to trend scales is important to understand possible impacts of global warming on the water cycle and for evaluation of model-based climate projections.

ENSO and volcano signals can be determined for tropical and global fields of surface temperature, column water vapor and precipitation. Removal of these inter-annual signals allows for a clearer determination of the inter-decadal/trend signals and allows for a clear comparison of the two time scales.

For ENSO inter-annual variations temperature and water vapor signals remain "strong" when integrated over both the tropics and the globe, while precipitation signals become muted. For volcanoes the precipitation signal remains similar to that of water vapor.

For trends temperature and water vapor increase, while precipitation trend is close to zero—similar to ENSO variations .

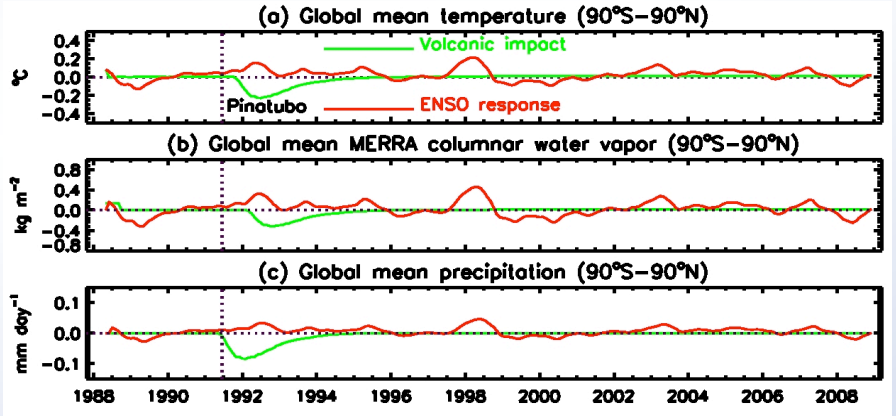
However, while precipitation variations are globally weak relative to water vapor and temperature, there are key regional (latitudinal) variations due probably to stronger dynamical influence for precipitation and energy budget constraints.

Inter-annual (ENSO and Volcano)

Surface Temp. (Amplitude ~ .2C)

Water Vapor (~ 7%/C for ENSO, ~6%/C for volcano)

Precip. (~ 2%/C for ENSO, ~4%/C for volcano)

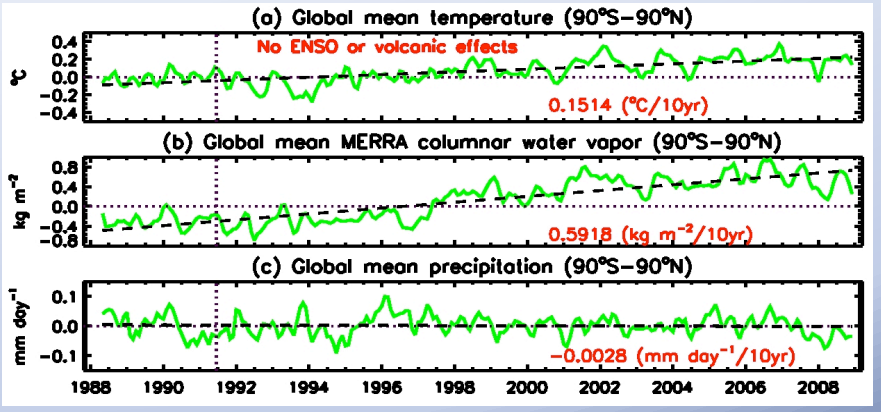


Trends

Surface Temp. (.15 C/10yr)

Water Vapor (~ 7%/C, taking into account MERRA trend bias)

Precipitation (~ 0%/C)



Satellite data sets are emphasized in this study and are supplemented by MERRA reanalysis results. Significant resources are expended under NEWS funding to produce the Global Precipitation Climatology Project (GPCP) global precipitation data set and to develop integrated observational analyses for large-scale, atmospheric water cycle analysis. The GPCP data set has been utilized in over 1000 journal publications, indicating the value of this NEWS-supported precipitation analysis.

Extreme Rainfall Events over the US Great Plains (USGP) during the Last Decade

This study focuses on identifying extreme warm season (April-September) rain events over the central US Great Plains (100°-95°W and 35°-45° N) using NASA's multi-satellite measurements (TRMM-3B42) and understanding atmospheric processes associated with these events using North American Regional Reanalysis (NARR)

Extreme Event: When daily rain amount exceeds 95 percentile value from 2000-2009 daily rain measurements (spatial resolution: approximately 25x25 km^2 area)

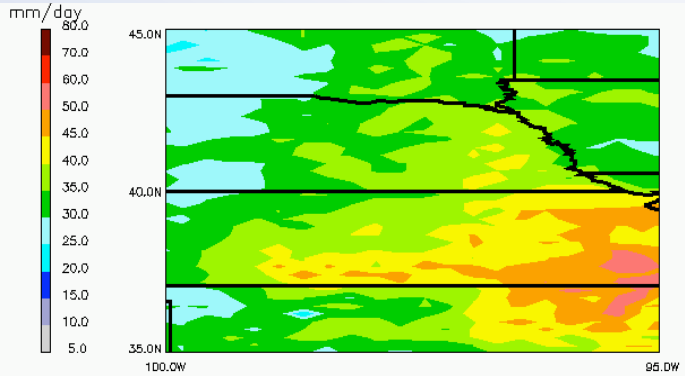


Figure 1: 95 percentile value > 35 mm/day over eastern Great Plains with much larger values (> 50mm/day) over southeastern region

Extreme Rain Frequency: Number of days exceeding the 95 percentile value

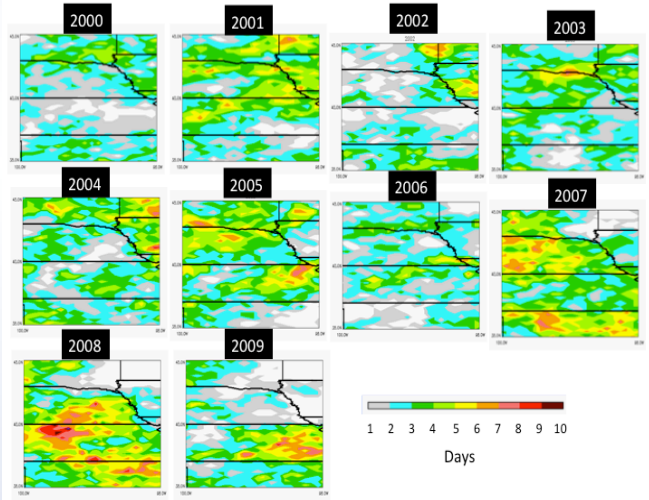


Figure 2: Extreme warm season rain frequency over the last decade range from 1-10 days with large-scale spatial organization and substantial interannual variability

On the average extreme rain events cover 1-2% area of the USGP per day

The rain frequency was minimum in 2006 and maximum in 2008

Northward wind at 925 hPa level (top) and eastward wind at 200 hPa (bottom) from NARR (Difference between 2008 and 2006 April-September seasonal values)

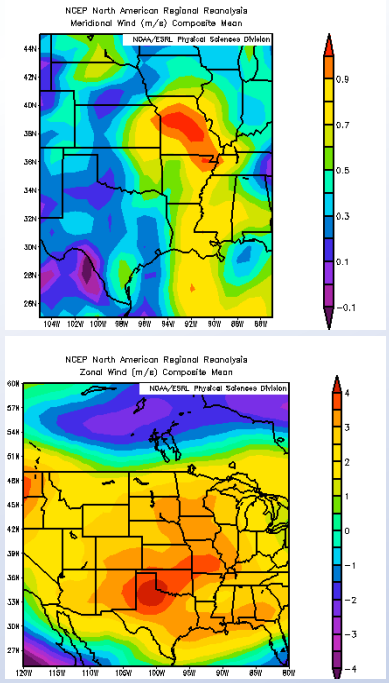


Figure 3: Eastward shift in low-level northward wind jet (top) and southward shift in upper level eastward wind jet (bottom) in 2008 compared to 2006 suggest large-scale dynamical controls on the extreme rain frequency over the USGP

Amita Mehta and Eric Smith
amita.v.mehta@nasa.gov

This study is supported in part by NASA Energy and Water Cycle Studies Program
Theme: Drought and Flood Extremes

9/3/10

A Study of Arctic Clouds and Radiation Budget Supported by a NASA NEWS Project

Principal Investigator: Xiquan Dong (dong@aero.und.edu)

NASA ENERGY AND WATER CYCLE STUDY

Recent climate modeling results have revealed that the largest disagreement between climate model simulations of present-day climate is found in the Arctic region. **To provide more observational evidence related to the investigations of Arctic clouds and their impact on surface radiation budget, a 10-yr record of Arctic cloud fraction and radiative forcing has been generated using data collected at the Atmospheric Radiation Measurement (ARM) North Slope of Alaska (NSA) site and the nearby NOAA Barrow Observatory (BRW) from June 1998 to May 2008.** Long term analysis results indicate that the annual cloud coverage is about 0.778 with a minimum of 0.574 in March and a maximum of 0.965 in September. Compared with other studies, it was also found that infrared heating by clouds does not change over the Arctic regions significantly, but the total cloud induced radiative heating changes from negative to positive from Alaska to the Beaufort Sea. **This result indicates that Barrow is near the critical latitude for which cloud induced infrared radiative heating is in approximate balance by that changes in cloud induced solar radiation.**

These results should be valuable for enabling climate modelers to quantitatively evaluate climate model simulations over the Arctic region, leading to identification of source for modeling errors and possible cloud-radiation formulation improvements.

Dong, X., B. Xi, K. Crosby, C.N. Long, R. Stone and M. Shupe, 2010: A 10-yr Climatology of Arctic Cloud Fraction and Radiative Forcing at Barrow, Alaska. *J. Geophys. Res.,* 115, D17212, doi:10.1029/2009JD013489 (Published Sept. 15, 2010)

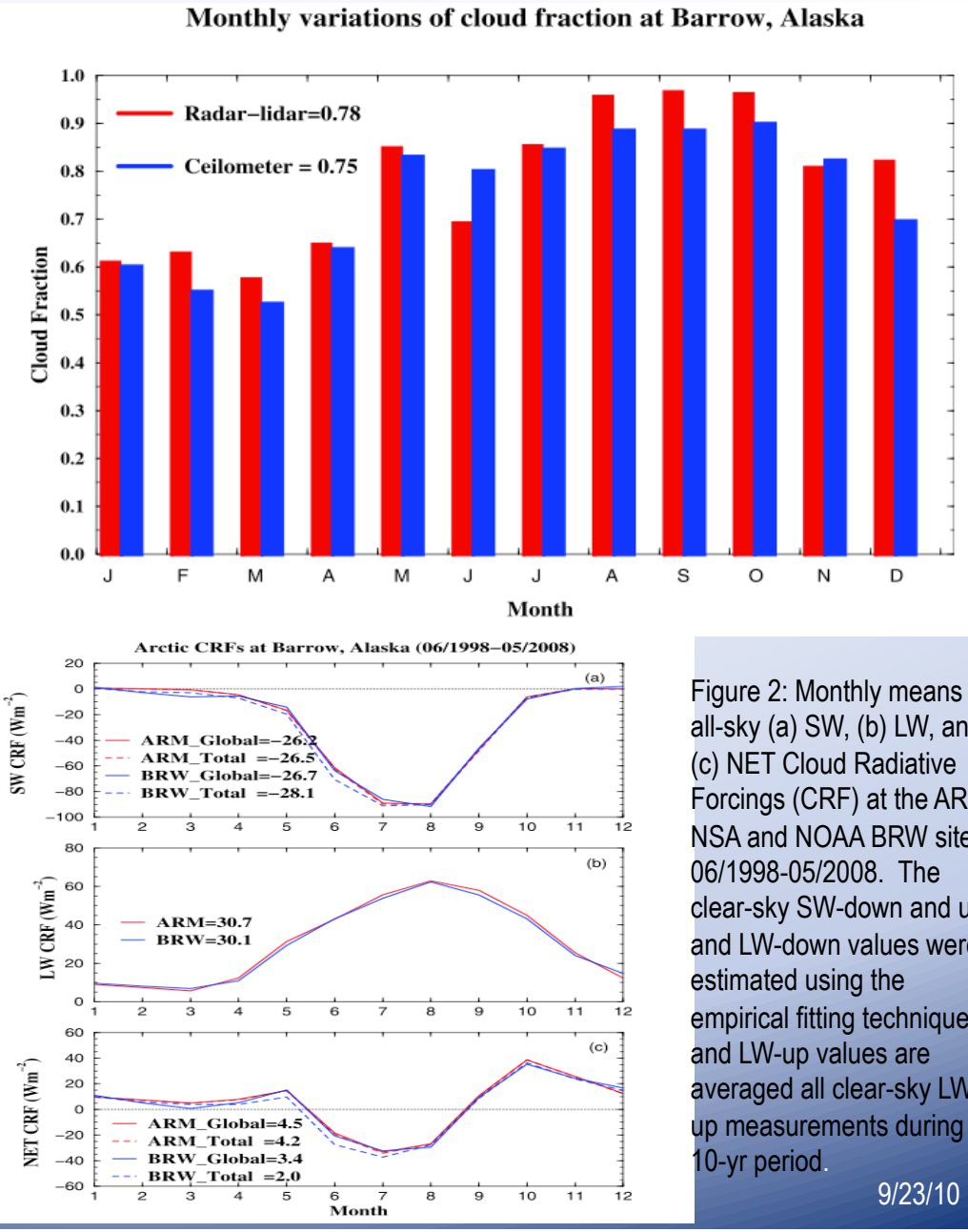


Figure 2: Monthly means of all-sky (a) SW, (b) LW, and (c) NET Cloud Radiative Forcings (CRF) at the ARM NSA and NOAA BRW sites, 06/1998-05/2008. The clear-sky SW-down and up, and LW-down values were estimated using the empirical fitting techniques, and LW-up values are averaged all clear-sky LW-up measurements during the 10-yr period.

9/23/10

Shifts in Extreme Precipitation Events Based on Resolved Atmospheric Fields

Investigators: C. Adam Schlosser, Dara Entekhabi, Xiang Gao, and Erwan Monier (MIT)

Among the more compelling issues of potential climate change is the fate of extreme events, which present some of the highest risks and impacts on infrastructure and managed systems. However, climate models cannot reliably predict extreme precipitation, even though they are able to resolve the large-scale atmospheric motions and patterns that lead to precipitation extremes. Therefore, this project aims to quantify the relationship between atmospheric fields at the climate scale (obtained from data constrained by satellite observations) with observed occurrences of extreme precipitation events. Then, the shifts in the frequency and strength of these atmospheric patterns (from climate model simulations) will provide a corresponding indicator of changes in the frequency and magnitude of extreme precipitation - under a range of climate-change scenarios.

Gao, X., C. Adam Schlosser, M. Weber, and D. Entekhabi, 2009: Shifts in Extreme Precipitation Events Based on Resolved Atmospheric Fields, NEWS PI Meeting, Columbia MD, December, 2009.

This study is made possible in part through the efforts of the NASA Energy- and Water- cycle Study that has been focusing on extremes in the Earth system using NASA satellite and model data products. (see http://nasa-news.org

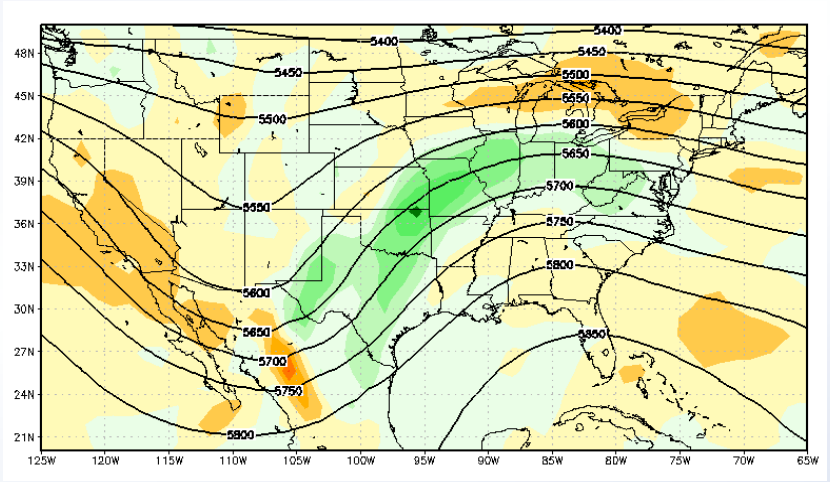


Figure 1 Composite of 500mb geopotential height (contours) during days with widespread extreme precipitation events over the southern United States during the spring. The situation depicts a well-defined trough to the west of the region, which supports advection of warm, moist air and upper-level divergent flow, confirmed with corresponding composites of 300mb divergence locations (green shaded regions).

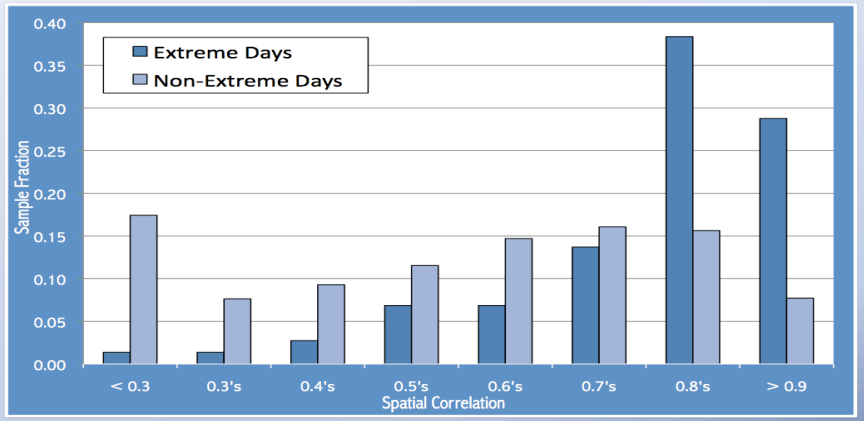


Figure 2. Frequency distributions of the spatial correlation of the composite 500mb geopotential height (Fig. 1) against days in which no widespread extreme events occurred (light blue bars) as well as for the days in which widespread conditions were met (dark blue bars). Skewness toward higher correlations as well as compression in the distribution indicates the composite pattern's predictive capability.

Effects of Satellite Observing System Changes on NASA Reanalysis Water and Energy Fluxes

NASA Energy and Water Cycle Study

Pete Robertson (MSFC) and Mike Bosilovich (GSFC)

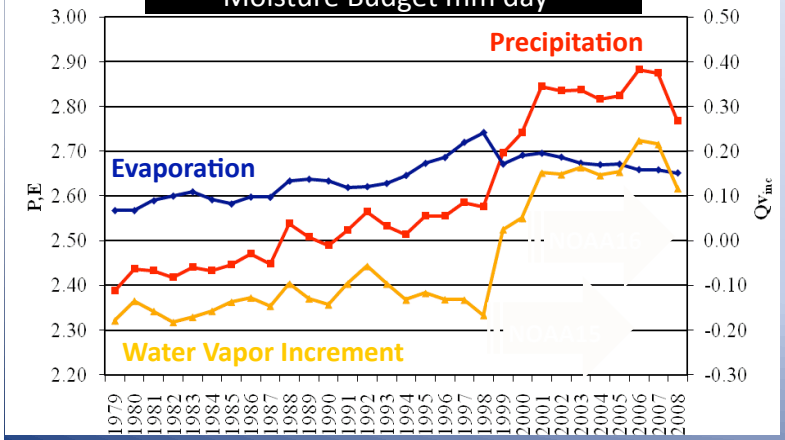
Robertson, F. R., M. G. Bosilovich, J. Chen and T. L. Miller, 2011: The effect of satellite observing system changes on MERRA water and energy fluxes. J. Clim. (submitted to MERRA special collection).

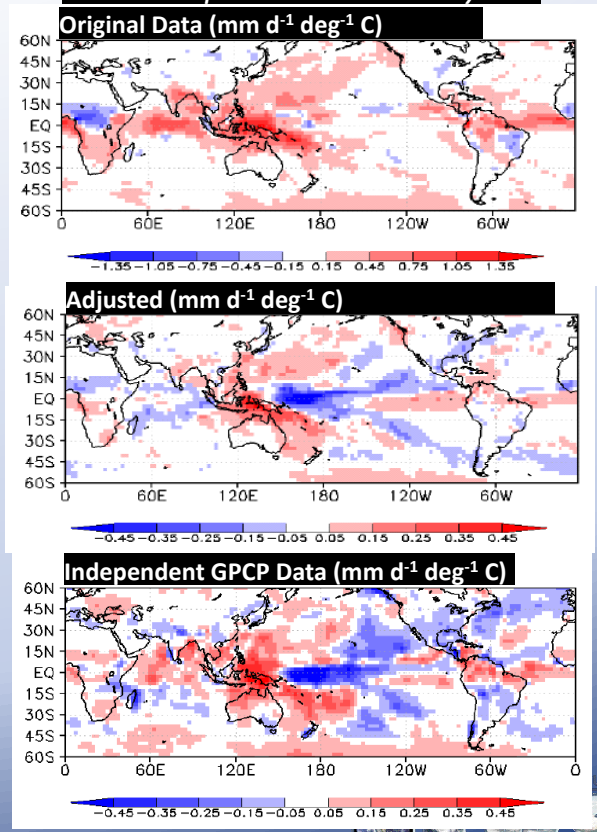
Adjustment strategy via Principal Component Analysis removes spurious signals and enables broader use of MERRA data set by science user community.

MERRA – the ***M****odern-****E****ra* ***R****etrospective analysis for* ***R****esearch and* ***A****pplications* is NASA's data assimilation methodology for integrating Earth Observations into a coherent estimate of the evolving state of the planet's atmosphere and land surface.

- Every 6h in the evolving global forecast, the model projections are compared to available observations.
- Model departures from observations (increments) are saved and used as additional forcing terms in the dynamical equations. *Thus the model state solution is constrained to be consistent with observations…*

Global Mean Time Series of MERRA Moisture Budget mm day^{-1}



… but time-dependent biases in water and energy fluxes result from evolving satellite observing system measurement capabilities interacting with less than perfect physics in the NASA GEOS-5 assimilation model.

Leading Mode of Decadal Precipitation Variability